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ABSTRACT

A study worked toward designing a small set of phonological, letter, and memory tasks that would allow teachers and other school personnel concerned with early intervention in reading to reliably identify children likely to develop reading disabilities (RD). A total of 446 kindergarten children from diverse geographic (west and east coasts), community (urban/rural), and economic (middle/low socioeconomic status) conditions were tested and followed through first grade. The strategy involved: (1) establishing selection measures and scoring criteria; (2) testing the parameters on a new cohort of children from a different geographic location, socioeconomic level, and ethnicity; (3) exploring the relative accuracy of RD predictors gathered in kindergarten and at the beginning of first grade; and (4) testing the contribution to RD prediction of including a measure of dynamic segmentation in which children received varying levels of prompts. Discriminant analysis based on a small set of predictors gathered in kindergarten or early first grade yielded high hit rates in distinguishing children who exhibited an RD profile at the end of first grade. Measures taken early in first grade were more accurate discriminators of future RD than were measures taken later in kindergarten, which in turn were more discriminating than measures taken early in kindergarten. Whereas phonemic segmentation and rapid letter naming qualified as primary discriminators of RD at all three screening windows, three other tasks were primary discriminators at some but not other screening windows. (Contains 24 references, 4 tables, and 5 figures of data. Two kindergarten tests are attached.) (Author/RS)

Early and Later Prediction of Reading Disabilities

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Abstract

The goal of this study was to was to work toward designing a small set of phonological, letter, and memory tasks that would allow teachers and other school personnel concerned with early intervention in reading to reliably identify children likely to develop reading disabilities (RD). We tested children in kindergarten and followed them through first grade, layering the investigation by testing various cohorts from diverse geographic (west and east coasts), community (urban/rural), and economic (middle/low SES) conditions. Our strategy involved (1) establishing selection measures and scoring criteria by calibrating early indicators of RD on a cohort of children tested in kindergarten and followed through Grade 1; (2) testing the parameters on a new cohort of children from a different geographic location, socioeconomic level, and ethnicity; (3) exploring the relative accuracy of RD predictors gathered in kindergarten and at the beginning of first grade; and (4) testing the contribution to RD prediction of including a measure of dynamic segmentation in which children received varying levels of prompts to assist them in performing the task. Discriminant analysis based on a small set of predictors gathered in kindergarten or early first grade yielded high hit rates in distinguishing children who exhibited an RD profile at the end of first grade. Depending upon the timing of the screenings and the cohort studied, underprediction ranged from zero to 9 percent and overprediction from 4 to 17 percent. Measures taken early in first grade were more accurate discriminators of future RD than were measures taken late in kindergarten, which in turn were more discriminating than measures taken early in kindergarten. Whereas phonemic segmentation and rapid letter naming qualified as primary discriminators of RD at all three screening windows, three other tasks were primary discriminators at some but not other screening windows.

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Some children experience extraordinary difficulty in learning to read, falling behind their peers early and sometimes permanently. The relative stability of achievement standing following one or two years of reading instruction is a serious concern for children with reading disability, because once behind, these children's chances for full recovery diminish (Stanovich. 1988). This situation has given rise to efforts at early intervention that better prepare children for the first stages of formal reading instruction, perhaps preventing or reducing problems in reading acquistion and their deleterious consequences. Early identification of children who are likely to have difficulty learning to read constitutes the first step in preventing subsequent reading problems (Berninger, Thalberg, BeBruyn, & Smith, 1987; Blachman, 1994; Clay, 1993; Taylor, Short, Frye, & Shearer, 1992).

Although many factors influence the course of reading acquisition, individual differences in certain cognitive and language skills exhibited in kindergarten or first grade relate to later reading achievement. These include phonological manipulation skills such as rhyming, blending, sound isolation, and segmenting (Berninger, 1986; Juel, 1988; Maclean, Bradley, & Bryant, 1987; Stanovich, Cunningham, & Cramer, 1984; Share, Jorm, Maclean, & Matthews, 1984; Uhry, 1992; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993), letter knowledge (virtually all studies that measured letter knowledge in kindergarten or early first grade), vocabulary (Bowers & Patel, 1988; Mantzicopoulos & Morrison, 1994; Scarborough, 1995), short term memory for language-related information (Mann and Ditunno, 1990; Rapala & Brady, 1990), and efficient retrieval of verbal labels (Bowers & Swanson, 1991; Doi & Manis, 1996; Seidenberg & McClelland, 1989; Wolf, 1991). The significant predictive correlations between each of these skills and reading during the primary grades are robust across studies and measures.

Despite discovery of these reading related cognitive and language skills, predicting exactly which children will develop reading disabilities (RD) has proved problematic. Several researchers have used discriminant analysis to classify children as more or less likely to develop severe reading acquisition problems (Catts, 1991; Felton, 1992; Hurford, Johnston, Nepote, Hampton, Moore, et al., 1993; Torgesen, Burgess, Wagner, & Rashotte, 1996); however, two types of errors reduce the prediction of RD. Errors of underprediction occur when the predictive measures miss children who subsequently develop RD (Coleman & Dover, 1993; Torgesen, et al., 1996). Measures such as vocabulary or concepts about print, although moderately related to later reading achievement, can lead to underprediction of RD because some children who will develop RD, especially those who are older than their peers at the time of testing or those who come from homes rich in literacy experiences, may perform better on these measures than non RD children who are younger or who come from more impoverished literacy circumstances. Measures that underpredict RD are of concern for those interested in early intervention because they directly undermine the intent of the early intervention efforts (i.e., identifying those students who require early, intense, and targeted instruction).

The second type of error, overprediction, occurs when predictive measures mistakenly identify non RD children as at risk for becoming RD. Some of the measures that have the highest correlation with subsequent reading achievement (e.g., phonological segmentation) are difficult for many non RD children when tested early in kindergarten, resulting in substantial overprediction errors. When intervention services are costly (e.g., Reading Recovery or other one-to-one instruction) or lead to significant changes in childrens' educational placements (e.g., assigning children to self-contained classrooms for children with reading difficulties and other learning/behavioral problems), overidentification errors not only squander limited educational resources, but may even prove harmful to individual children. Part of the challenge facing researchers is to create measures of early developing, reading related skills that are at an appropriate level of difficulty for the age of children who are tested.

Our goal in the present study was to work toward designing a small set of phonological, letter, and memory tasks that would allow teachers and other school personnel concerned with early intervention in reading to reliably identify children likely to develop RD. We endeavored to develop measures that could be administered within the time constraints that typically govern screening efforts, that required minimal technology and material costs, and that did not suffer from serious over or underprediction errors. Our approach was to test children in kindergarten and follow them through first grade, layering the investigation by testing various cohorts from diverse geographic (west and east coasts), community (urban/rural), and economic (middle/low SES) conditions. We used the first cohort of children to calibrate a model for predicting reading acquisition problems, using predictors gathered in the fall and spring of kindergarten; next, we collected the same data from a new cohort of children to test the replicability of the model and to refine scoring criteria for the most promising measures; last, we repeated our tests with a larger cohort of children, adjusted the timing of the tests and added a dynamic measure of segmentation ability in an effort to reduce the number of children whose kindergarten performance suggested they would encounter reading difficulties, but whose later performance surpassed expectations.

Method

The Three Cohorts

Over the course of four years, we followed three cohorts of children from kindergaten through first grade, measuring each cohort on three occasions, the last of which was a reading test given at the end of first grade. We used this last measure as our criterion for classifying children as exhibiting or not exhibiting RD. For two of the cohorts, we collected predictive measures in November and April of kindergarten; for the third, we collected predictive measures in November of kindergarten and October of first grade. Altogether, 446 children participated in the 3 cohorts.

Cohort 1. Children were enrolled in kindergarten for the first time in one of 12 classes in four schools in a district located in a mid-sized agriculturally based community in the Pacific Northwest. To enable comparisons of this study with others predicting reading disability, we dropped 17 children who scored lower than 70 on the Peabody Picture Vocabulary Test-Revised (most of these for low English ability) and 13 others who were older than 6.1 years in September of kindergarten, leaving a final sample of 129 children with complete sets of measures. Thirty to 40 percent of students in each school qualified for free or reduced lunch; the majority of children were Caucasian; approximately 10% of the children spoke Spanish at home. Children who met the selection criteria and had already been identified for special education services or who were in the referral process (4 children) were included.

Cohort 2. We tested all kindergarten children (N = 157) from three inner-city schools in a large urban district in the northeastern United States, including only children who scored higher than 70 on the PPVT-R, were 6.1 years or younger in September of kindergarten, and were still available for testing at the end of first grade, giving us a final sample of 101 children with three complete sets of measures. The ethnicity of this sample was 51% African American, 48% Caucasian, and 1% Other. In all schools, over 60% of children qualified for free or reduced lunch; in one school more than 80% qualified for free or reduced lunch.

Cohort 3. One year later, we revisited the same schools that composed Cohort 1 and added one additional school from the same district, giving us 215 children with complete sets of scores by the end of first grade. In contrast to the measurement procedures used with the first two cohorts, we administered the second prediction battery during October of first grade instead of near the end of kindergarten.

Predictors in Kindergarten

Descriptive measures. The Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981) is an individually administered, norm-referenced measure of receptive vocabulary, with a mean of 100 and sd of 15.

Sound repetition. For this test, children repeated isolated phonemes separated with a half-second pause ("Let's play copy cats. Say exactly what I say: /p/ /i/ /f/"). Items varied from two to four phonemes in length. We report the number of correct items.

Rapid letter naming. Examiners showed children a card with 60 randomly ordered letters in large, upper-case type, and asked them to name as many of the letters as they could in 1 minute.

Phonological Measures. Each task included three unscored practice items with feedback, followed by ten scored items. The examiner also provided the correct response during test administration when children made incorrect, partial, or no responses.

Syllable blending and segmenting. Children guessed words presented as separated syllables ("teach--er;" "di--no--saur") or said words in syllables, tapping the table as they did so.

Syllable deletion was based on Berninger's (1986) modification of the Rosner Test of Auditory Analysis (Rosner & Simon, 1971), which she expanded to 10 items for the kindergarten level. Examiners stated a word ("Baseball"), and asked the child to say the word minus one syllable ("Say it again, but don't say base").

Blending. Items were presented in an onset-rime format for the November assessments (Examiners said, "What word is this? s--oap"), and as 3 phonemes separated by a brief pause for the April assessments (Examiners said, "What word is this? s--oa--p").

Segmenting. Children segmented one-syllable spoken words into 2 or 3 phonemes (Examiners said, "Make. Tell me the sounds in make."). Children received 1 point for a correct subsyllable portion of the word (e.g., the first or last sound, or any portion of the word) or 2 points for segmentation at the onset-rime or phoneme levels (m--ake or m--a--ke).

First sound isolation. The examiner said, "Tell me the first sound in *sick.*" Items were scored correct if the child provided *only* the first sound (e.g., for *pill*, /p/ or /puh/ was correct; /pi/ was not).

Rhyme production. Following an explanation and examples, the examiner said: "Say a word that rhymes with *make.*" Correct responses included real and nonsense words. For incorrect responses, the examiner modeled correct alternatives. Five items were administered in November, and ten items in April.

Dynamic segmentation. For children in Cohort 3 who scored less than 80% correct on the segmentation test in October of first grade, we administered a dynamic segmentation task, following procedures developed by Slocum (Slocum, O'Connor, & Jenkins, 1993) for teaching children to segment into onsets and rimes across learning trials. Each of the three trials began with a testing trial of five new words. If the child segmented fewer than four words correctly, three teaching phases followed, each phase continuing until the child could segment four of the five words correctly with the level of prompt provided. The phases included: (1) Model and ask the child to repeat each of the five words ("Dog. Say it this way: d--og.") while demonstrating with

Elkonin boxes (Elkonin, 1973); (2) Ask the child to segment the five words using the Elkonin boxes without a teacher model; and (3) A trial without prompts or boxes. When the child could correctly segment at least four of the five words, the next trial began with a testing trial on a new set of five words.

The score for each trial was the number of words correctly segmented during the testing trial (i.e., on the novel word set). When the child correctly segmented four of five words on the novel set, we discontinued training and awarded any remaining trials with a score equal to the number correct on the last administered set. Total words correctly segmented ranged from 0-15. We also totalled the number of repetitions needed for each child to master each set of five words across the three learning trials; total trials ranged from 0-66.

First Grade

We administered the word identification and word attack portions of the Woodcock Reading Mastery Tests (WRMT: Woodcock, 1987) in May of first grade. On the word identification test, children read a list of words shown by the examiner; on the word attack test, children read pseudowords.

Criteria for reading disability classification. Most children who develop RD are not identified for special education by the end of the first grade year, so we used two processes for classification purposes. First, children who had already qualified for RD through special education procedures by May of first grade (e.g., two children in Cohort 1, three in Cohort 2) were assigned to the RD group. In addition to those formally classified, we assigned children to the RD group who scored 1.4 or more standard deviations below the mean on the combined word identification and word attack subtests from the WRMT.

Timing of test batteries. All children received their end of first grade measures in May. We administered the first battery of kindergarten measures to each cohort in November, and the second set of measures for Cohorts 1 and 2 in April of kindergarten; for Cohort 3, we collected these measures, including dynamic segmentation, in October of first grade. Because these children had already begun reading instruction, we also included in October a short screening of reading, which consisted of a list of 10 high frequency, regularly spelled words.

Results

Cohort 1

Discriminant function analysis of November and April kindergarten scores. For both kindergarten test periods, we submitted all variables to a discriminant analysis, then proceeded through backward selection to eliminate variables that were less useful in predicting group membership. Our goal was to find the smallest set of predictors that accurately identified children who would develop RD by the end of first grade. At each step of the discriminant analysis, we tabulated the predicted and actual group membership to determine the effect of dropping predictors on correct classification of the RD children.

November predictors. The canonical correlation between all kindergarten measures in November obtained from the first cohort and group membership at the end of first grade was .54, and the canonical correlation when a vector representing only the small set of predictors (segmentation, rapid letter naming and syllable deletion) was regressed on the RD/non RD classification was .51 (Wilks' lambda = .745). The net result of restricting the set of predictors was to increase from 13 to 15 the number of children predicted to have RD, but who scored in the non RD range on the WRMT (i.e., false positives), yielding an overprediction rate of 12%. All children with RD profiles were selected.

Table 1. Structural Coefficients (Canonical Loadings) for the Variables Administered in November and April of Kindergarten Predicting RD in Cohort 1 (n = 129)

	November: All Predictors	November: Best Predictors[a]	April: All Predictors	April: Best Predictors[a]
Age[b]	0.206			
Blend Syllables[b]	0.343			

Segment Syllables[b]	0.377			
PPVT-R	0.501		0.407	
Rhyme Production	0.489		0.521	
Syllable Deletion	0.908	0.996	0.754	
Rapid Letter Naming	0.392	0.429	0.558	0.777
Segment Phonemes	0.442	0.485	0.545	0.761
Blend Phonemes	0.238		0.342	
First Sound[c]			0.599	
Sound Repetition[c]			0.549	0.762
Canonical Correlation	0.540	0.505	0.628	0.496

[a] Smallest set of predictors to correctly classify all children who developed reading disability.

[b] Not included in April

[c] Not included in November

April predictors. By the end of kindergarten, the canonical correlation between all April variables and group membership was 0.62. The complete set of measures produced one false negative--a child who developed RD but was not identified in April. Reducing the set of predictors to segmentation, rapid letter naming and sound repetition at the end of kindergarten reduced the correlation to 0.496; however, the smaller set accurately identified all of the children who developed an RD profile. It is likely that high scores on easier measures (e.g., syllable deletion, rhyme production or first sound identification) obscured the persistent difficulties that contribute to problems with initial reading acquisition (e.g., segmentation, memory for sounds, letter knowledge).

Table 2. Classification Rates for the Small Sets of November and April Predictors for Cohort 1

November: Phoneme Segmentation, Rapid Letter Naming, and Syllable Segmentation

		Predicted Status		
		Not at Risk	At Risk	Total
Observed Status	Average Readers	106	15	121
	Reading Disabled	0	8	8
Total		106	23	129

April: Phoneme Segmentation, Rapid Letter Naming, and Sound Repetition

		Predicted Status		
		Not at Risk	At Risk	Total
Observed Status	Average Readers	102	19	121
	Reading Disabled	0	8	8
Total		102	27	129

Cohorts 1 and 2 Combined

The stability of a set of predictors is particularly important for the utility of this kind of research; therefore, we used data from the first cohort to specify a set of predictors and data from the first and second cohorts combined to determine whether that set of predictors would continue to function accurately when more children were added to the sample. The children in Cohort 2 differed in geographical location, ethnicity, and socioeconomic status, however, the results are similar to those derived from Cohort 1 alone. The small set of predictors at the end of kindergarten correctly identified all 15 of the children classified as RD at the end of first grade, but also identified 30 non RD children (an overprediction rate of 12%, similar to that observed in the smaller sample).

Table 3. Classification Rates for the Small Sets of November and April Predictors for Cohorts 1 & 2, Combined

November: Phoneme Segmentation, Rapid Letter Naming, and Syllable Deletion

Predicted Status

		Not at Risk	At Risk	Total
Observed Status	Average Readers	178	37	215
	Reading Disabled	0	15	15
Total		178	52	230

April: Phoneme Segmentation, Rapid Letter Naming, and Sound Repetition

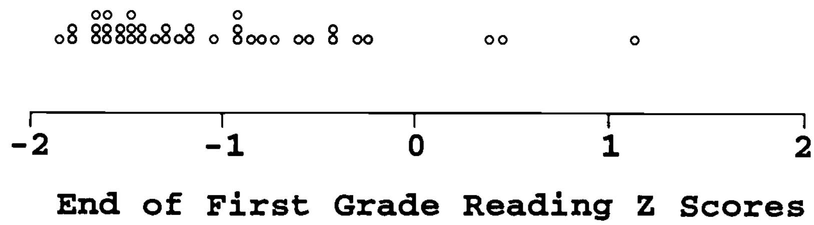
		Predicted Status		
		Not at Risk	At Risk	Total
Observed Status	Average Readers	185	30	215
	Reading Disabled	0	15	15
Total		185	45	230

Identifying scoring criteria for the predictors. We identified the maximum scores on the kindergarten measures obtained by children with RD in the combined sample to determine whether useful scoring criteria could be generated for the small set of measures selected through the discriminate functions. Table 4 (last page) shows the maximum scores that formed the basis for scoring criteria. By selecting children who scored at or below these values, we identified all children with RD in both cohorts. Using these criteria for selection also reduced (relative to the discriminant analysis) the number of false positives, and allowed a closer examination of children incorrectly classified.

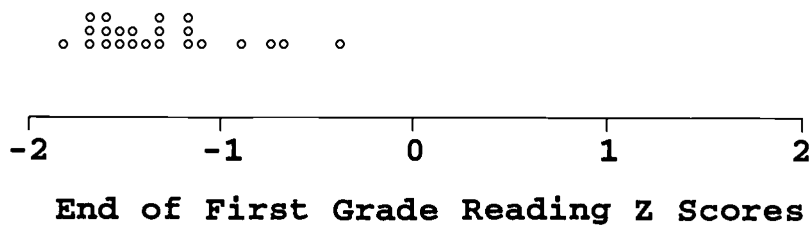
Figure 1 shows end of first grade reading z-scores (combined word identification and word attack scores, expressed as standard deviations from the mean) of all children who fell below the cut-off scores on all three predictors in November and April. In November, cut-off scores captured 38 children, or 17% of the combined sample, and included all 15 children with RD plus 23 who were not RD. Note that only 3 of the selected children scored at or above the sample mean reading performance at the end of first grade. Using cut off scores instead of discriminant analyses to select children at risk for RD reduced the number of false positives (i.e., overprediction).

Figure 1

Scoring criteria on November measures = RLN < 13; Seg < 5; Rosner < 5



Scoring criteria on April measures = RLN < 16; Seg < 8; Sound repetition < 11



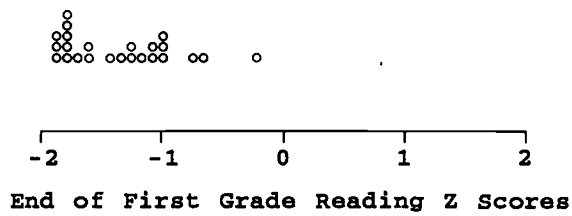
By April cut-off scores were more accurate, capturing all of the children with RD, and only 8 false positives. Examination of the Figure 1 reveals that none of the overselected eight children displayed above average reading a year later, and four of the eight read approximately one standard deviation below the mean performance of Cohorts 1 and 2, combined.

Cross Validation of Kindergarten Discriminant Analysis: Cohort 3

Two years later, we returned to Cohort 1's school district to cross validate our findings from the first two cohorts. In November of kindergarten we tested all of the children in five elementary schools, and applied the discriminant analysis techniques used for the earlier cohorts. Using segmentation, syllable deletion, and rapid letter naming, 10 of the 11 children with RD were accurately selected, however, these measures missed one child who had a higher syllable deletion score than any of the children with RD in the first two cohorts. Applying new (higher) cut-off scores from these measures raised the criterion score for syllable deletion to <9 and selected 24 students: 11 with RD and 13 others. The z scores on end-of-first-grade reading for these children are shown in Figure 2.

Figure 2. Cohort 3

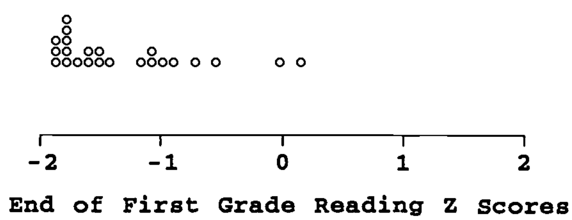
Expanded November Scoring Criteria: Rosner < 9; RLN < 6; Segmenting < 4



Scores from the October of first grade screening were the subject of the next discriminant analysis. Using segmentation, rapid letter naming and sound repetition, we captured all 11 of the children who exhibited RD profiles at the end of first grade, along with 26 others. Using the maximum scores on October measures obtained by first graders with RD, we established new cut-off scores for segmentation, rapid letter naming, and sound repetition. These scores selected 23 children: 11 with RD and 12 others.

Figure 3. Cohort 3 , October, First Grade,

Scoring Criteria: RLN < 17; Segmentation < 15; Sound Repetition < 11



Dynamic assessment. Children's ability to segment words was dramatically higher in October of first grade than at the end of kindergarten. By October, the modal segmentation score was 20; over half scored 75% or higher on the segmentation measure. We administered the dynamic segmentation measure to the first grade children who scored less than 80% correct on the static segmentation measure. For the purpose of analysis, children who did not take the dynamic segmentation test (because they had scored at least 80% on the segmentation measure) were assigned dynamic scores of 15 (range 0-15) for 'words segmented correctly' on the 3 novel word sets, and 0 (range 0-66) for the 'total number of learning trials' needed to be able to segment the three lists accurately. We ran another discriminant function substituting the number of words segmented correctly on the dynamic segmentation measure for the score on the static phoneme segmentation measure. This substitution had little effect on classification rates, identifying all children with RD and reducing by 1 the number of children incorrectly classified as RD. Running the analysis again, this time substituting the second dynamic segmentation score (total number of learning trials needed to learn to segment) resulted in missing one child with RD (the same child who was missed in the November screening); however, it reduced from 25 to 9 the number of number of false positives (overselection errors). The classification rates for each measure of segmentation in October of first grade are shown in Table 4.

Table 4. Classification Rates for Cohort 3 Using Discriminant Analyses

November K Scores: Phoneme Segmentation, Syllable Deletion, Rapid Letter Naming

		Predicted Status		
		Not at Risk	At Risk	Total
Observed Status	Average Readers	175	29	204
	Reading Disabled	1	10	11
Total		176	39	215

October of First Grade: Phoneme Segmentation, Sound Repetition, Rapid Letter Naming

		Predicted Status		
		Not at Risk	At Risk	Total
Observed Status	Average Readers	178	26	204
	Reading Disabled	0	11	11
Total		178	37	215

October of First Grade:

Dynamic Segmentation (words segmented correctly), Sound Repetition, Rapid Letter Naming

		Predicted Status		
		Not at Risk	At Risk	Total
Observed Status	Average Readers	179	25	204
	Reading Disabled	0	11	11
Total		179	36	215

October of First Grade:

Dynamic Segmentation (learning trials), Sound Repetition, Rapid Letter Naming

		Predicted Status		
		Not at Risk	At Risk	Total
Observed Status	Average Readers	195	9	204
	Reading Disabled	1	10	11
Total		196	19	215

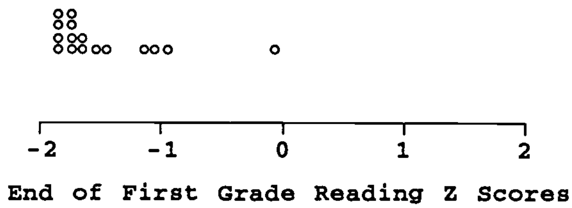
Establishing cut-off scores for dynamic segmentation posed a problem, because one child with RD learned to segment very rapidly (the same child missed by the discriminant analysis), requiring only one learning trial. If we remove this child from the pool for determining cut-off scores, then the next lowest score among children with RD is 14. Using this score as the 'trials to criterion' cut-off, along with RLN and Sound repetition, resulted in the lowest rate of overprediction (6 children), and, as Figure 4 shows, only one of these children attained average literacy by the end of first grade. This information must be balanced, however, against this criterion's failure to identify one of the children who developed an RD profile six months later.

Table 4. Demographics, Means, Standard Deviations, and Maximum Scores for Cohorts 1 and 2, by Reading Disability Classification

	Cohort 1 (N=129)				Cohort 2 (N=102)			
	Average (n=121)		RD (n = 8)		Average (n=94)		RD (n=8)	
Ethnicity	AA C O		AA C O		AA C O		AA C O	
	5 106 10		1 6 1		47 45 2		4 4 0	
	Mean (SD)	Maximum[a]	Mean (SD)	Maximum	Mean (SD)	Maximum	Mean (SD)	Maximum
Age September 1	5.4 (0.3)	6.1	5.6 (0.3)	6.1	5.4 (0.3)	6.1	5.5 (0.4)	6.1
Kindergarten: Nov.								
PPVT-R[b]	100.5 (12.4)	129	83.8 (15.8)	110	95.60 (16.0)	133	83.5 (15.5)	112
Rhyme (5)	2.9 (2.0)	5	0.3 (0.7)	2	3.5 (1.9)	5	0.6 (1.1)	3
Blend Syllables (15)	12.2 (3.9)	15	8.5 (5.9)	15	11.4 (3.9)	15	4.9 (4.7)	8
Segment Syllables (15)	11.4 (3.7)	15	7.5 (5.0)	15	11.5 (4.3)	15	4.8 (5.1)	12
Syllable Deletion (10)	7.2 (2.8)	10	0.6 (1.4)	4	5.5 (3.8)	10	0.5 (0.8)	4
Rapid Letter Naming	15.2 (12.8)	61	2.2 (3.4)	10	30.5 (17.0)	70	4.5 (2.1)	12
Sound Repetition	NA		NA		8.1 (2.4)	12	5.4 (2.7)	9
Blend Phonemes (10)	4.1 (3.1)	10	1.6 (1.3)	4	3.6 (3.5)	10	0.4 (0.6)	3
Segment Phonemes (20)	7.5 (6.1)	20	1.0 (1.1)	3	5.4 (5.5)	19	0.7 (1.4)	4
Kindergarten: April								
Rhyme (10)	8.3 (1.8)	10	0.5 (0.9)	2	9.1 (2.0)	10	2.3 (2.7)	7
Syllable Deletion (10)	8.1 (2.1)	10	3.4 (3.4)	6	8.5 (2.4)	10	2.4 (2.3)	5
Rapid Letter Naming	35.5 (16.7)	77	5.8 (5.4)	15	41.4 (13.4)	73	9.6 (2.6)	13
Blend Phonemes (10)	6.9 (4.8)	10	1.7 (1.6)	4	6.8 (3.8)	10	2.3 (3.9)	11
Segment Phonemes (20)	17.1 (6.1)	20	0.6 (0.8)	2	13.2 (5.8)	20	1.4 (2.6)	7
First Sound (10)	7.2 (2.7)	10	2.3 (2.7)	6	9.4 (1.5)	10	2.6 (2.4)	7
Sound Repetition (12)	10.0 (1.5)	12	7.1 (1.1)	8	9.8 (1.6)	12	6.5 (1.9)	10
First Grade: April								
Word identification[d]	101.64 (14.00)	135	75.24 (2.69)	79	112.1 (14.0)	139	78.8 (4.2)	84
Word attack[d]	101.31 (14.56)	136	80.19 (0.91)	81	111.7 (18.5)	136	79.4 (3.1)	85

a Highest score earned by any member of the group; b Peabody Picture Vocabulary Test-Revised; c Numbers in parentheses following measure name indicate highest possible score; d Subtest from the Woodcock Reading Mastery Test (standard scores)

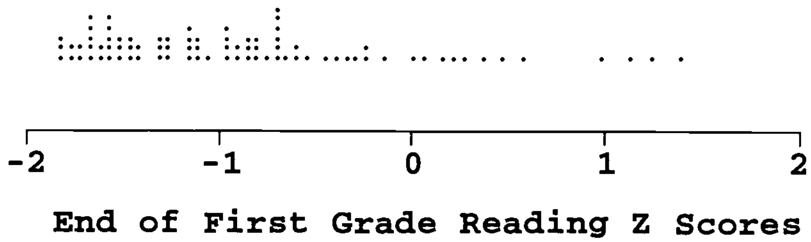
Figure 4. Children in Cohort 3 selected from First Grade Scoring Criteria, substituting Trials to Criterion on the dynamic segmentation measure for the static measure.



Cross Validation of Cut-Off Scores. Application of the selection criteria developed from the kindergarten November scores of the first two cohorts to the November scores of children in Cohort 3 missed identifying two children with RD. In both cases, the children scored higher on the measure of syllable deletion (November scores of 6 and 8, respectively) than any children with RD in the first two cohorts, where the highest syllable deletion score obtained by a child with RD was 4. Raising the criterion on syllable deletion to <9 caught both children, but this also greatly increased the number of children predicted to develop RD. In fact, if this higher cut-off for syllable deletion were substituted and applied to the November scores of all three cohorts combined, 19% of the children (83 of 446) would be predicted to develop RD, a number that includes 12 children who at the end of first grade scored at or above the sample's mean reading level. Figure 5 shows reading z-scores of children in all three cohorts who were selected by the more liberal syllable deletion standard, in combination with earlier established criteria for letter naming and segmentation.

Figure 5

Using most liberal scoring criteria from November measures to select poor readers in 1st Grade.



Discussion

Discriminant analyses based on a small subset of predictors gathered in kindergarten or early first grade yielded high hit rates in distinguishing children who exhibited an RD profile at the end of first grade. Depending upon the timing of the screenings and the cohort studied, underprediction ranged from zero to 9 percent and overprediction ranged from 4 to 17 percent. Measures taken early in first grade were more accurate discriminators of future RD than were measures taken late in kindergarten, which in turn were more discriminating than measures taken early in kindergarten.

However, an examination of the classification rates derived from predictive measures that are taken at a single point in time (i.e., early or late kindergarten, or early first grade) and for a single cohort leaves out two important parts of the story. First, selecting specific tasks that are most useful in distiguishing children who will exhibit RD is dependent on the timing of the screening effort. Second, cut-off scores on various screening measures that accurately distinguished RD in one cohort had reduced predictive validity for other cohorts.

Across the three cohorts, rapid letter naming and phonemic segmentation tasks were included among the subset of strong predictors of RD at all three screening points. Whereas phonemic segmentation and rapid letter naming qualified as primary discriminators of RD, three other tasks were primary discriminators at some but not other screening windows. One such task was syllable deletion, which qualified as a primary discriminator at the November screening window, but at later screenings its place was taken by sound repetition. In addition, the stability of syllable deletion as a predictor of future RD was also called into question by the results of the cross validation. We observed a reduction in the accuracy of RD discrimination at the November screenings in Cohort 3 relative to the first two cohorts, and this reduction stemmed from performance on the syllable deletion task. Whereas no RD children from Cohorts 1 and 2 obtained scores higher than four on syllable deletion, two RD children in Cohort 3 obtained scores of six and eight on this task. In contrast, maximum scores on rapid letter naming and phoneme segmentation tasks of Cohort 3 children who developed RD did not exceed those obtained by RD children in the previous cohorts.

In April, the ability to repeat sounds was a primary discriminator of future RD, but its status as a primary discriminator in early kindergarten is less clear because the sound repetition task was not part of the November screening for Cohort 1. We did include it for subsequent cohorts, and discriminant analyses of the November screening results for Cohorts 2 and 3 selected all children who later developed RD, with overprediction rates of 18-20%. Despite these relatively high overprediction rates for reading disability, of the 48 children in both cohorts selected, only four scored higher than the sample mean z-scores on end of first grade reading.

Dynamic phonemic segmentation also served as a primary discriminator in October of first grade. Whether this task would have discriminative value earlier is uncertain because it was not used in the kindergarten battery. But even a first grade dynamic segmentation task required considerable time to conduct and many children found it difficult. This raises doubts about its utilility as a screening task before first grade.

Also noteworthy was that receptive vocabulary was unhelpful in discriminating RD. This measure correlated significantly with reading development, but we found that including PPVT-R in the discriminant analysis of RD weakened classification accuracy, because it appeared to exert a protective factor in the discriminant function, making children with RD who had strong vocabularies more difficult to detect--even though, on average, children with RD earned lower PPVT-R scores.

Setting Criterion Scores: Alternative Solutions

We endeavored to design a screening procedure for use in kindergarten or early first grade that would select: (1) all children (i.e., no underprediction) whose reading scores at the end of first grade revealed a pattern of RD, and (2) few children (i.e, small overprediction) whose reading scores at the end of first grade did not reveal an RD pattern. Given the results of the cross-validations, our ambition appears to have outdistanced our abilities; with each successive cohort we were required to liberalize the preceding criterion scores in order to capture every child who subsequently developed an RD profile. Moreover, raising criterion scores increased overprediction rates, sometimes substantially. Cohort 3 provided the most sobering cross-validation where two children with RD were missed when we applied the criterion scores developed from November scores of Cohorts 1and 2. We considered several alternatives for setting criterion levels that might result in greater validity.

Liberalizing Criterion Scores on Prediction Tasks. One alternative is to treat the three cohorts (all 446 children) as one group, and then reformulate (more liberal) scoring criteria based on the scores of all RD children. Resetting the November criterion levels on syllable deletion to <9 and retaining the previous criteria for rapid letter naming and segmentation (<13 and <5, respectively), captures all 26 children who exhibit an RD profile at the end of first grade; however, these criteria predict that almost 19% of the kindergartners will develop RD at the end of first grade. As Figure 5 shows, the majority of the 83 children selected through this method read below grade level at the end of first grade (76% of the selected children read more than .5 sd below the mean), although 12 of the 83 children read at or above grade level a year and a half later.

Employing different predictive tasks. A second possibility for improving RD screening involves adding to or substituting for the current set of predictive tasks. For example, substitution of sound repetition for syllable deletion in the November screening captures all children with RD in the last two cohorts. Although substituting sound repetition identified children in Cohort 3 missed using the more stringent cut-off score for syllable deletion, the effect of this substitution on predicting RD in Cohort 1 cannot be determined because we had not developed this task at the time of the November screening for Cohort 1. Nevertheless, we believe it is a possibility worth testing with new groups of children, because none of the Cohort 1 children with RD scored higher than 8 on sound repetition in April.

Settling for some underprediction of RD. By using the maximum scores that RD children obtained on the prediction tasks, we gave priority to identifying every child likely to exhibit RD at the end of first grade. The trade-off for maximizing RD identification is a high number of false positives. An alternative strategy is to settle for some underprediction of RD. Were an 82% correct identification rate of RD acceptable, then application to Cohort 3 of the original criterion scores developed from Cohorts 1 and 2 would yield an overprediction rate of 7%. Were the criterion score on phoneme deletion raised to <7, then correct identification of RD in Cohort 3 would rise to 91% with 1.4 false positives for every correctly identified child with RD.

Screening Later. A fourth alternative for improving screening accuracy may be to delay screening. Accuracy rates of the predictive tasks for correctly classifying RD and non RD groups were higher with later screening. Pilot work had disclosed that September to October of kindergarten was too early for the measures we used in the present study. Had we conducted the screening prior to November of kindergarten we would have greatly increased the number of false positives as well as the number of children who decline to participate in the tasks. Likewise, we observed improved classification rates in April, relative to November for Cohorts 1 and 2 combined. Screening results in first grade also yielded few false positives when the primary predictors included a learning trials score from dynamic segmentation. Within-cohort comparisons of early and late screenings suggest that later screening reduces rates of overprediction.

Using the smallest set of predictors. For our cohorts and measures, no set of predictors was 100% accurate in identifying all children with RD across all cohorts, unless we set liberal cut off scores, which resulted in sizable over identification of children with RD (i.e., nearly 20% of the population). Importantly, however, a subset of measures requiring less than 15 min to administer was as effective in identifying children who later developed reading problems as was our much larger, more time consuming original battery of tests. In addition, our results suggest that a layered approach to identification may be feasible. Among these three cohorts of children who began kindergarten for the first time at 6.1 years old or younger, no children who ended first grade 1.4 SD's or more below the mean on real and nonword reading scored as high as the average score on rapid letter naming or phoneme segmentation. Further research might explore whether administering just these measures, followed by further assessment for children who score below mean scores could be more efficient, without losing accuracy.

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Appendix A

Kindergarten November Tests

Segment words into onset-rime. "This time I will say a word, and you tell me two sounds in the word. My turn. I can say the sounds in *Mike*. M--ike. Your turn. Say the sounds in Mike." (to correct: "I'll say the sounds in Mike. M--ike. Say the sounds in Mike."). Ex: *shop*; *cat* Score 1 point for 1 correctly segmented sound; 2 points for onset-rime or complete segmentation (total = 20).

1. soap______________________
2. van______________________
3. food______________________
4. show______________________
5. make______________________
6. leaf_________________
7. fall___________________
8. no_________________
9. mad_________________
10. zoo________________

Syllable deletion (Berninger, 1986) Score 1 point each (total = 10).

Training words:		
Say *dumptruck*	again, without *dump*	
Say *dollhouse*	again, without *house*	
Say:	Now say it again, but don't say:	Child's Response:
1. baseball	base	
2. cowboy	cow	
3. sunshine	sun	
4. paper	pa	
5. cucumber	cu	
6. picnic	nic	
7. morning	ing	
8. seesaw	saw	
9. bunny	ny	
10. farmer	er	

Rapid Letter Naming   Time: 1 minute   Number correct:________

D	N	B	H	F	I	M	O	A	R
S	E	W	Y	L	T	C	X	G	K
B	F	O	J	A	S	P	R	U	E
M	Z	K	C	T	Q	N	J	P	X
U	G	Q	L	W	Z	I	V	Y	D
V	H	D	N	B	H	K	C	T	A

Kindergarten April Tests

Segment words into onset-rime. "This time I will say a word, and you tell me two sounds in the word. My turn. I can say the sounds in *Mike*. M--ike. Your turn. Say the sounds in Mike." (to correct: "I'll say the sounds in Mike. M--ike. Say the sounds in Mike."). Ex: *shop*; *cat*

Score 1 point for 1 correctly segmented sound; 2 points for onset-rime or complete segmentation (total = 20).

1. soap________	6. leaf________
2. van________	7. fall________
3. food________	8. no________
4. show________	9. mad________
5. make________	10. zoo________

Sound repetition: Practice with /a/, /m/, p -- a

(1 sec pause between each sound and before child responds; discontinue after 5 cons. errors).

Score 1 point for each item (total = 12).

1. s -- k________	5. m -- a________	9. a -- m -- ss________
2. n -- d________	6. t -- ay________	10. t -- a -- t________
3. ee --f________	7. z -- ee -- p________	11. m -- ee -- k -- i________
4. p -- i________	8. k -- a -- f________	12. p -- a -- s -- f________

Rapid letter naming, as in November battery

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